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Ser. No. 09/982,317
Filed 10/18/01

COMPARISON OF MULTIPLE ACCESS SCHEMES FOR UMTS

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Abstract - An assessment of several multiple access schemes against UMTS criteria has been carried out within the FRAMES project. Based on this comprehensive evaluation, an harmonized multiple access platform has been designed consisting of two modes, a wideband TDMA with and without spreading and a wideband CDMA, which is presented hereafter. Both modes are compared against UMTS criteria. In general, they can both fulfill the UMTS objectives and will form the FRAMES input into UMTS standardization. However, Mode 1 seems more suitable for bursty type of traffic and in addition to FDD for asymmetric TDD operation while Mode 2 suits better for moderately varying circuit switched data in public radio environments.

I. INTRODUCTION

The European Research Program ACTS (Advanced Communication Technologies and Services) started in the end of 1995 to support collaborative mobile research and development. Within ACTS the project FRAMES (Future Radio Wideband Multiple Access System) has been set up with an objective to define an UMTS radio access system. The first goal of FRAMES was to investigate different multiple access technologies and based on a thorough evaluation of several candidate schemes to select the best combination as a basis for further detailed development of UMTS radio access system.

CDMA and TDMA based technologies have been studied extensively for 3rd generation mobile radio systems. The RACE II projects CODIT [8] and ATDMA [9] have created system concepts based on DS-CDMA and advanced TDMA techniques, respectively. These concepts have been validated with trial systems. Comparison between CODIT and ATDMA radio interfaces was carried out in SIG5 [10]. The main results of this comparison have shown that there is no fundamental difference between these concepts from a performance point of view. Other issues related e.g. to implementation will play a more important role when selecting 3rd generation multiple access technology. Thus, in addition to the evaluation of spectrum efficiency FRAMES has considered a number of other criteria covering the main UMTS objectives like full coverage and mobility for bit rates up to 144 kbit/s, limited coverage and mobility for bit rates up to 2 Mbit/s and high flexibility to introduce new services to all radio operating environments [1,2]

The rest of the paper is organized as follows. In Chapter II a summary of the multiple access comparison results is presented together with some reasoning for the selection of the FRAMES Multiple Access (FMA). In Chapter III a description of FMA is presented and in Chapter IV evaluation results of the two FMA modes against UMTS criteria are presented. Finally, conclusions are drawn in Chapter V.

II. MULTIPLE ACCESS COMPARISON

FRAMES Multiple Access evaluation consisted of two stages. At the first stage several candidate schemes were compared and schemes with similar characteristics combined. The results of this stage were two multiple access schemes with three options for both[3,4]:

- multicarrier TDMA (multiples of 200 kHz), single wideband TDMA (WB-TDMA, bandwidth 1-2 MHz) and hybrid CDMA/TDMA (bandwidth 1.6 MHz)
- asynchronous CDMA (WB-CDMA, bandwidth 6 MHz), OFDM/CDMA and synchronous CDMA

At the second stage these schemes were extensively evaluated with respect to the following criteria :

- Radio related properties which covered aspects like provision of various data rates in different environments and bearer service flexibility, Spectrum efficiency (capacity), Coverage, Support for adaptive antennas, Hierarchical Cell Structures (HCS), Duplex method, support for public and private environments. Handover
- Terminal impacts (Power consumption and complexity, GSM/UMTS dual mode terminals)
- BSS impacts (Evolution from existing systems, BSS complexity and cost)

In the following the main results of the analysis are presented. WB-TDMA is flexible for TDD with asymmetric services and it is optimized for high bit rate services. Main concern is the complexity of the equalizer in large cells. Hybrid CDMA/TDMA provides good performance both for voice and data. The spreading eases somewhat delay spread handling in tough radio propagation conditions. However, it has high complexity due to joint detection for low bit rate services. WB-CDMA is flexible for circuit switched variable rate services due to its good multirate capabilities. The

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unpredictable nature of packet switched services will cause some problems e.g for power control. A drawback of WB-CDMA is that it requires large chunks of spectrum even for low bit rate services. It also seems less suitable WB-CDMA for asymmetric services in TDD mode.

The above considerations led us to combine WB-TDMA and hybrid CDMA/TDMA into Mode 1 (WB-TDMA with and without spreading) and to harmonize WB-CDMA parameters with that to form the Mode 2 of the FRAMES Multiple Access (FMA). In addition, backwards compatibility with GSM/DCS was kept as a key cornerstone of FMA concept facilitating easy implementation of GSM/UMTS dualmode terminals.

Three multiple access options were dropped from further consideration due to complexity and performance reasons. Multicarrier TDMA has too complex RF. OFDM/CDMA considered only for downlink had low performance with reuse one [11] but could be considered as a modulation method for Mode 1. Synchronous CDMA had low performance due to the lack of fast power control.

Even though multicarrier TDMA was considered too complex, a single carrier enhanced GSM, i.e. a 200 kHz carrier with linear modulation instead of GMSK, was considered as a viable option. An enhanced GSM can offer higher data rates 150-200 kbit/s with binary modulation and 300-400 kbit/s with quaternary modulation. Advantages are:

- Can co-exist on GSM carriers - Easy evolution
- Easy dual mode terminals implementation
- Well harmonized with GSM *and* FMA
- Low spectrum granularity - Efficient with hierarchical cell structures (HCS)

III. FRAMES MULTIPLE ACCESS (FMA)

In accordance with the general purpose of UMTS as a third-generation mobile telecommunications system encompassing a wide range of application areas, communication services and different deployment scenarios, FMA must offer a multi-level and open platform i.e. a concept to cater for current and future developments of UMTS radio interface standards. FMA supports the two modes

- wideband TDMA with and without spreading, and
- WB-CDMA

where Mode 1 consists of two options; wideband TDMA optimized for high bit rate packet data, and wideband TDMA with spreading.

The main features of the FMA modes are presented in Table 1. In Mode 1 users are separated orthogonally into time slots, and within each slot an additional separation by spreading codes can be used. In Mode 2, wideband direct sequence CDMA is used, i.e., users are separated by different spreading codes, while continuous transmission is used. In Mode 1 the basic transmission unit is one slot. This basic unit is then divided into smaller units, either subslots or spreading codes if the spreading feature is used. In this way, we achieve a smaller granularity, i.e. step size in bit rate, and a higher flexibility in service provision from low to high bit rates. Note that high bit rates can also be implemented by this fine structure, in order to obtain higher multiplexing gain and flexibility. In Mode 2 the basic transmission unit in the resource space is code. On the downlink, parallel multicode transmission is used, which means that higher bit rates can be supplied by allocating more codes to one user. On the uplink, transmission resources are adaptively allocated by varying the spreading ratio. In addition to the basic resource allocation by slots and codes, the data rates of both modes are further adjusted by puncturing the basic channel code rates or by repetition coding.

FRAMES Multiple Access has a discrete wideband carrier selection which means that e.g. in the Mode 1, the carrier spacing B could equal 1.6 MHz, while in the Mode 2, B could equal 6.4 MHz, i.e., four times the carrier spacing as in the former mode. Both modes will allow for two carrier bandwidths (3.2 and 12.8 MHz respectively) to make the bandwidth selection flexible depending on the service and/or environment. For Mode 1 a bandwidth of 3.2 MHz provides a trade-off between larger bandwidth with QPSK modulation

Table 1. Main features of FMA Mode 1 and 2 (N/A= not applicable, DL =downlink, UL= uplink)

	Mode 1: WB-TDMA with and without spreading	Mode 2: WB-CDMA
Multiple-access method	TDMA or TDMA/CDMA	Direct-Sequence CDMA
Channel spacing	1.6 MHz	6.4 MHz
Carrier chip/bit rate	1.55 - 4.74 Mbit/s or Mchip/s	5.2 Mchips/s
Interference reduction	Both intra and intercell with joint detection	Only intra cell with multiuser detection in the uplink
Spreading codes	Orthogonal spreading codes of length 16 chips	Short codes from 2 chips up to 512 chips
Multirate concept	DL & UL: Multislot and Multicode	DL: Multicode UL: Variable spreading
Variable bit rates	Supported	Supported on a frame-by-frame (10 ms) basis
Detection	Coherent, based on Midamble	DL: Coherent detection (pilot-code based) UL: Coherent detection (reference-symbol-based)
Handover	Mobile assisted	Mobile controlled soft handover
Interfrequency handover	same as normal handover	Burst transmission mode (uplink) Dual receiver structure (downlink)
Frequency hopping	Frame-by-frame/slot-by-slot	N/A

and smaller bandwidth with multilevel 16-QAM modulation and for Mode 2 the larger bandwidth of 12.8 MHz offers better performance for 2 Mbit/s users.

The harmonization of bandwidths presented above, together with a careful selection of the basic parameters, enables the derivation of the fundamental frequencies of both FMA modes from a single 26 MHz clock which is also used as a GSM mobile station reference clock. This makes backwards compatibility to GSM easier and reduces implementation costs as well since only one reference oscillator is needed whatever the access scheme.

An important new feature of the FMA proposal is joint detection[1] capability (i.e., of more than one transmission link in the radio system), which increases the spectrum efficiency of a cellular network. Joint detection is used to remove either intracell or intercell co-channel interference or both. For wideband TDMA with spreading joint detection is used both in the uplink and the downlink to cancel intracell interference and for wideband TDMA to cancel intercell interference. For wideband CDMA (Mode 2), multi-user detection is used only for the uplink in order to avoid undue complexity of hand-portable terminals; moreover, the additional gain from multi-user detection would not be very high due to the high processing gain and orthogonal spreading codes in the downlink.

Both modes use coherent detection. Mode 1 uses midambles for channel estimation and Mode 2 a varying number of reference symbols in the uplink and a continuous pilot channel in the downlink.

Mode 1 is based on a fundamental TDMA structure with spreading feature with time frame length of 4.615 ms Depending on the radio environment and service, the frame and burst structure can be dynamically adapted via link adaptation. The training sequences need to be optimized to fully support adaptive-antenna techniques and interference cancellation techniques. The frame structure of wideband TDMA without spreading is described in Figure 1. It has two slot sizes : 1/16 slot and 1/64 slot. For the 1/64 slot there are two burst formats.

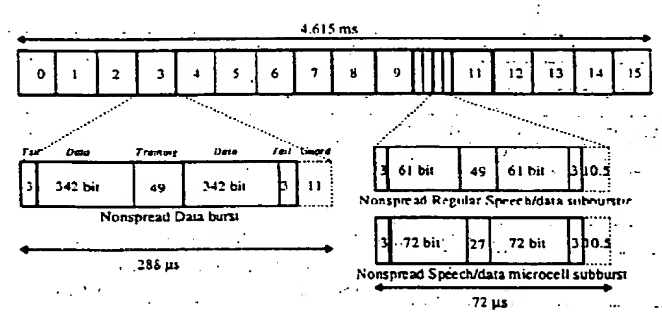

Figure 1. Wideband TDMA frame structure

[1] Note: the terms 'multi-user detection' and 'interference cancellation' are also sometimes used.

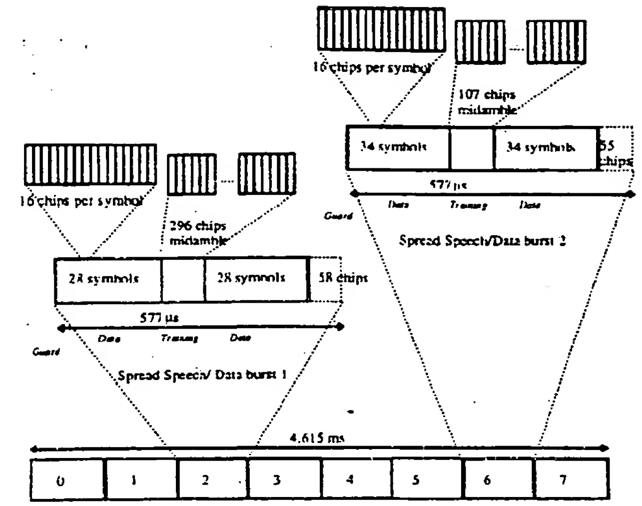

Figure 2. Frame structure of WB- TDMA with spreading

The frame and burst structures of wideband TDMA with spreading are presented in Figure 2.

In Mode 2, the frame structure is based on a frame length of 10 ms as depicted in Figure 3 for the uplink. The multirate scheme facilitates multiplexing of different services with different quality of service and adding as well as dropping services during a call.

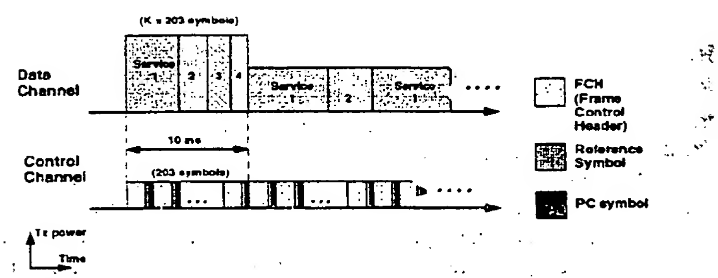

Figure 3. Mode 2 Wideband CDMA uplink frame structure and service multiplexing example

In Mode 1, the data modulation is Binary Offset QAM, or Quarternary Offset QAM for the 2 Mbit/s service in the non-spread case. The spreading modulation for Mode 1 is linearized GMSK. In Mode 2, dual-channel O-QPSK is used. At the initial stage of investigation, both modes have used traditional coding techniques (such as convolutional coding) with code rates from 0.4 to 0.7 and an inner CRC code for error detection capability. For higher Quality-of-Service requirements, concatenated coding (e.g. Reed-Solomon and convolutional codes) will be used. Novel coding schemes like Turbo-codes and combined coding and modulation will be investigated in the next phases of the FRAMES project. Interleaving for Mode 1 is either done on a frame-by-frame basis for low rate services or on a slot-by-slot basis for higher-rate services. In Mode 2, interleaving can span over one or several 10 ms frames.

Mode 1 has slow power control, with a 50 dB dynamic range, with an option to use faster power control on a burst basis. Mode 2 has fast power control, with 80 dB dynamic range based on open and closed loop control. The power control command rate is adaptable from 0.5 to 2 kbit/s.

IV. Evaluation against UMTS Criteria

Both modes can support the UMTS bit rates from low bit rates up to 2 Mbit/s. In Mode 1 variable bit rates with low granularity is supported by DTX or resource re-assignment together with adaptive coding. The slotted structure of Mode 1 suits well for bursty packet type of services. In Mode 2 variable bit rates are supported by adaptive coding and power assignments. Due to this power sharing and long initial synchronization Mode 2 is more suitable for moderately varying circuit switched services. For both modes different operating points for the services are obtained by different combinations of coding and link adaptation. In Mode 1 mixed bearer services can be provided to one user by packing them into different slots/codes while in Mode 2 mixed bearer services for one user can be multiplexed and have different operating points. For both modes bearers/services can be added and dropped during a call.

The spectrum efficiency for Mode 1 is presented in Table 2 and for Mode 2 in Table 3. Conditions prevailing for the spectrum efficiency simulations are summarized below :

- Hexagonal cell layout
- Uniformly distributed mobile stations
- 5% outage probability
- Path loss law with a decay factor of 3.6
- 10 dB shadowing parameter
- Power control used (except for Mode 1 mixed services)
- Errors due to power control and handover taken into account
- Mode 1 with spreading evaluated (orthogonal codes)
- For Mode 1 frequency re-use is optimized for each case
- In Mode 2 frequency re-use with cluster size 1

Spectrum efficiency figures in the downlink are very close to each other. Poor performance of mixed service in Mode 1 is

Table 2 Spectrum Efficiency of Mode 1

Service	Spectrum efficiency (kbps/MHz/cell), load/cluster order	
	downlink	**uplink**
12 kbps, BER = 10-3, 40 ms	124 77%/3	250 52%/1
144 kbps, BER = 10-3, 40 ms	126 70%/4	240 33%/7
Mixed services 90%/ 10% 12 kbps / 144 kbps	57 (no power control)	95(no power control)
2 Mbps, BER 10-3,100 ms	Downlink is limiting direction. Spectrum efficiency 100 - 150 kbps/MHz/s.	

Table 3. Spectrum Efficiency of Mode 2

	Spectrum efficiency (kbps/MHz/cell)	
Service	Downlink	Uplink (with Multiuser detection)
speech/low rate data 12 kbps, 10^{-3}, 40 ms	108	192
Medium data 144 kbps, 10^{-3}, 100 ms	108	389
Mixed services (12 kbps/144 kbps)	115	322
2 Mbps, 10^{-3}, 100 ms	Downlink is limiting direction. Spectrum efficiency 100 - 150 kbps/MHz/s.	

due to missing power control which was not used due to modeling difficulties. For both modes downlink is the limiting direction since uplink receiver antenna diversity was used. The better performance of Mode 2 in the uplink is due to multiuser detection. Multiuser detection efficiency i.e the amount of own cell interference that can be removed varies in different environments and here it was assumed to be 60 %.

Coverage evaluation was carried out for the same services and conditions as for spectrum efficiency. The access scheme dependent parameters determining range are :

- Link level performance Eb/N0
- The amount of overhead transmission

En/No figures taking into account the overhead transmission due to power control and training bits are presented in Table 4. The differences are very small and the uplink in the limiting direction due to lower transmission power. For low bit rate services Mode 1 has a slight advantage while for 144 kbit/s service Mode 2 has an advantage.

Non access scheme dependent parameters are

- Power, propagation conditions, planning margins, etc.

Table 4. Eb/No results

Mode 1		
E_b/N_0	Downlink	Uplink
Speech/low rate data 12 kbps, 10^{-3}, 40 ms	7.3 dB	3.4 dB
Medium rate data 144 kbps, 10^{-3}, 40 ms	5.9 dB	4.4 dB
Mode 2		
E_b/N_0	Downlink	Uplink
Speech/low rate data 12 kbps, 10^{-3}, 40 ms	6.9 dB	7.2 dB
Medium data 144 kbps, 10^{-3}, 100 ms	6.5 dB	3.1 dB

Both Modes support adaptive antenna techniques. In Mode 1 capacity gains are realized through smaller cluster sizes and in

Mode 2 by allocating more codes. SDMA can be used for C/I and capacity improvements. In Mode 2 user dedicated reference signal instead of common pilot signal is needed in the downlink.

Hierarchical cells are supported by interfrequency handover which in Mode 1 is inherent part of the system design and in Mode 2 is supported through discontinuous uplink transmission and dual receivers in the downlink. In both modes the mobile terminal assists with measurements for handover (MAHO). Handover between FMA-based UMTS and second generation (GSM) is supported through Dual mode terminals together with the capability of measuring GSM BCCH frequencies from FMA mode owing to the choice made above for the clock rate and frame structure.

Mode 1 is better suited for operation in private environments than Mode 2 since it requires less co-ordination. Mode 1 supports asymmetric data services well in TDD mode since number of slots between uplink and downlink can be varied. Mode 2 could in principle operate in TDD environment as well but the basic transmission scheme should be modified in that case and flexible allocation of resources between up and downlink is difficult.

In the evaluation of terminal impacts it can be noted that cost, size and power consumption for baseband complexity decreases drastically with time enabling more complex baseband algorithms like multiuser detection and interference cancellation. RF power consumption is mainly determined by the power level and linearity requirements of the output amplifier In macro cells with low bit rates, the RF power consumption dominates over baseband power consumption.

In Mode 1 wide bandwidth and high data rates gives stringent A/D converter requirements. There are higher requirements for power amplifier linearity of mobile stations for higher order modulation and multicode transmission. In Mode 2 power amplifier requirements are less stringent due to variable spreading gain in the uplink. In Mode 1 dual receiver is needed for inter-frequency handovers at higher data rates while in Mode 2 a dual receiver is always needed to support interfrequency handover. A dual mode UMTS and GSM/DCS terminal needs additional GSM/DCS duplexer and RF filters, but can re-use the same reference oscillator for both modes with careful parameter design.

Regarding BSS impacts, Mode 1 operates with hard handover. In Mode 2 soft handover is required meaning additional cost due to 1.5 times more transmission capacity plus diversity combining. In Mode 1 integration of new cells can be handled by slow dynamic channel allocation DCA to simplify network planning and in Mode 2 by automatic power planning.

V. CONCLUSIONS

A new harmonized multiple access platform has been presented based on an extensive assessment of several candidate multiple access schemes against UMTS criteria. The FRAMES Multiple Access (FMA) platform consists of two modes: a wideband TDMA mode with spreading (bandwidth 1.6 MHz) and a wideband continuous CDMA mode (bandwidth 6.4 MHz). Mode 1 contains two options, a wideband TDMA optimized for high bit rate packet data and wideband TDMA with spreading.

A detailed evaluation of FMA against UMTS criteria has been presented. Both modes can fulfill all UMTS criteria. Different modes show different advantages and disadvantages depending on the radio and service requirements. Mode 1 is more flexible to bursty and asymmetric service requirements and suits well both for FDD and TDD operation. Mode 2 appears more suited for moderately variable bit rate services for FDD and licensed spectrum.

ACKNOWLEDGMENTS

This work has been performed in the framework of the project ACTS AC090 FRAMES, which is partly funded by the European Union. The Authors would like to acknowledge the contributions of their colleagues from Siemens AG, Roke Manor Research Limited, Ericsson Radio Systems AB, ISM, Nokia Corporation, Technical University of Delft, University of Oulu, France Telecom CNET, Centre Suisse d'Electronique et de Microtechnique SA, ETHZ, University of Kaiserslautern, Chalmers University of Technology Ab, The Royal Institute of Technology, Instituto Superior Técnico.

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Das 12-16
Ser. No. 09/982,317
Filed 10/18/01

XP-002212948

C502000-0918-014

Title: 1xEV-DV Forward Channel Structure

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Bell Labs Innovations

PD 20-09-2000
P. 1-29 29

Date: September 20, 2000

Abstract: This contribution outlines the overall forward channel structure of the proposed 1xEV-DV system.

Recommendation: Discuss and adopt

1 INTRODUCTION

As defined by the CDG, 1xEV-DV is a common air-interface for the support of circuit-switched voice and data as well as packet-switched high speed data on the same spectrum. The concept proposal outlined in [1] is fully backward and forward compatible with 3G-1x. Towards this end, all defined channel structures as defined by 3G-1x are supported in the 2xEV-DV proposal. The support of packet-switched high speed data users is provided by means of a new, shared channel that serves one packet data user at a time in a time-multiplexed manner. A number of performance enhancing technologies are included in the 1xEV-DV proposal to ensure high peak and average packet data rates while supporting circuit switched voice and data and packet data on the same spectrum: asynchronous incremental redundancy [2], and multiple transmit antennas [3]. This contribution describes the forward link air interface of the 1xEV-DV concept proposal. The details of the reverse link air interface is given in [4].

2 FORWARD LINK CHANNEL TYPES

The Forward CDMA Channel consists of the channels specified Table 2.1. Table 2.1 also states the range of valid channels for each channel type.

Table 2.1 Channel Types on the Forward 1xEV-DV Channel

Channel Type	Maximum Number
Forward Pilot Channel	1
Transmit Diversity Pilot Channel	1
Auxiliary Pilot Channel	Not Specified
Auxiliary Transmit Diversity Pilot Channel	Not Specified
Synch Channel	1
Paging Channel	7
Broadcast Control Channel	8
Quick Paging Channel	3
Common Power Control Channel	4
Forward Common Control Channel	7
Forward Common Assignment Channel	7
Forward Dedicated Control Channel	1 per Traffic Channel
Forward Packet Data MAC Channel	1 (1xEV-DV only)
Forward Fundamental Channel	1 per Traffic Channel
Forward Supplemental Channel	7 (RC1,RC2), 2 (RC3-RC5, 1xEV-DV)

Forward Packet Data Channel	16 (1xEV-DV only)

The structure of the code channels transmitted by a base station is shown in Figure 2.1.

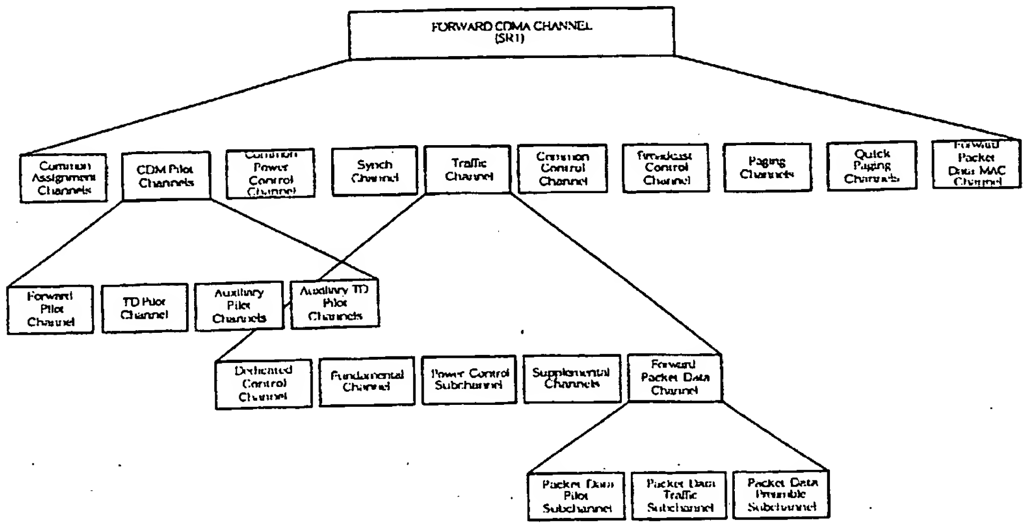


Figure 2.1 Forward CDMA Channel Transmitted by a Base Station

Each of these code channels is spread by an appropriate set of orthogonal Walsh functions. Each code channel is then spread by a quadrature pair of PN sequences at a fixed chip rate of 1.2288 Mcps.

The Forward Pilot Channel, Transmit Diversity Pilot Channel, Auxiliary Pilot Channel, Auxiliary Transmit Diversity Pilot Channel, Synch Channel, Paging Channel, Broadcast Control Channel, Quick Paging Channel, Common Power Control Channel, Common Assignment Channel, Dedicated Control Channel, Fundamental and Supplemental Channels are defined to be the same as their counterparts in the cdma2000 standard. Two new channels and one new configuration of an existing channel for the 1xEV-DV mode of operation are defined. These channels are described in the following sections.

3 FORWARD PACKET DATA CHANNEL

The Forward Packet Data Channel (FPDCH) is shared by packet data users based on time-multiplexing. The FPDCH consists of the following time-multiplied subchannels: the Packet Data Pilot Subchannel, the Forward Packet Data Traffic Subchannel, and the Forward Packet Data Preamble Subchannel. The Traffic Subchannel carries user data packets. Each subchannel is further decomposed into a number of code division multiplexed quadrature Walsh channels. The number of Walsh channels may vary in time [5].

Three different antenna schemes are possible within the FPDCH operation: Single Transmit Antenna, Selection Transmit Diversity (STD) with 2 transmit antennas and at least one receive antenna and finally, Multiple Input Multiple Output (MIMO) transmission with 2 transmit and at least 2 receive antennas [3]. A base station that is capable of providing STD and MIMO can switch between different schemes from user to user based on the feedback it receives from the mobile stations. The antenna scheme in use directly dictates the slot structure of the FPDCH.

Generically, the FPDCH consists of frames of length 20 ms. Within a frame, there are 16 slots, each of length 1536 chips, or 1.25 ms. Each frame is composed of two half-frame units of 8 slots.

Within each slot, the Pilot, and Traffic Channels are time-multiplexed. If the base station has only a single antenna, only one burst pilot is sent as seen in Figure 3.1. During idle periods, nothing is sent on the FPDCH in this case. If, on the other hand, the base station has two transmit antennas, there is the potential for some users to engage in MIMO or STD. These schemes require a separate pilot from each transmit antenna. Therefore, as seen in Figure 3.2 the FPDCH structure consists of two burst pilots that are code multiplexed.

These pilots are needed by the STD and MIMO users at all times. Thus, during idle periods, the entire slot is filled by the two burst pilots. Note however, that the total transmit power allocated to the two burst pilots remain the same regardless of whether FPDCH is in Active or Idle period.

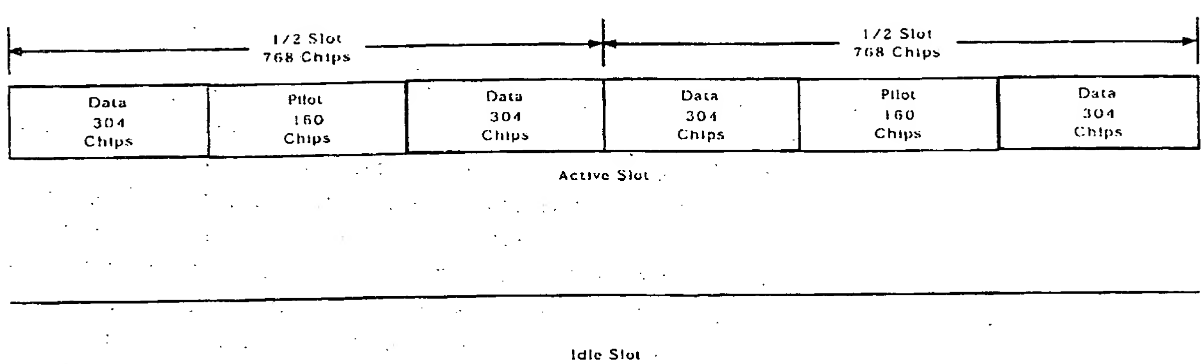


Figure 3.1 Slot Structure for the FPDCH when BS has one Transmit Antenna

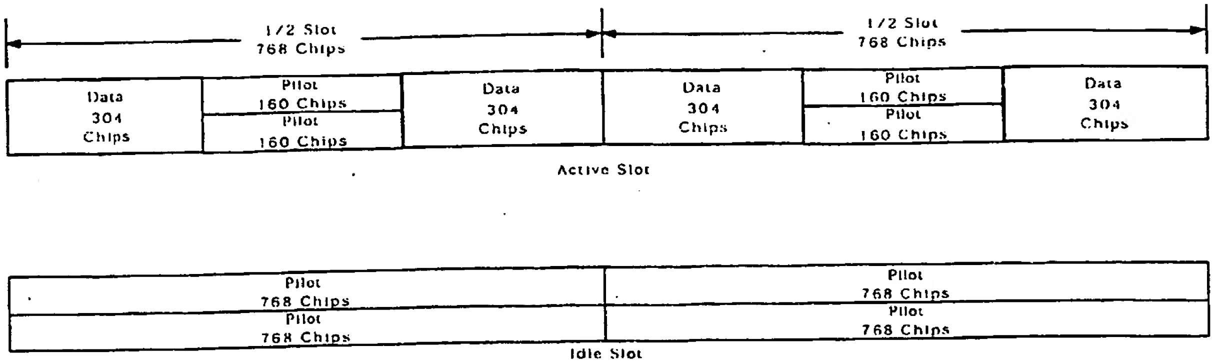


Figure 3.2 Slot Structure for the FPDCH when BS has two Transmit Antennas

3.1 Forward Packet Data Pilot Subchannel

The Forward Packet Data Pilot Subchannel consists of all-'0' symbols sent on the I channel on 1-2 different Walsh covers. Each Pilot subchannel needs to be covered by a different, orthogonal Walsh code. In FPDCH, each slot is divided into two half slots, each of which contains 1-2 pilot bursts. Each pilot burst has duration of 160 chips and is centered at the midpoint of the half slot. The number of Forward Packet Data Pilot Subchannels is dictated by the transmission antenna capabilities of the base station. If the base station employs single antenna transmission, only one Forward Packet Data Pilot Subchannel is necessary. If, on the other hand, the base station has two transmission antennas, then two code multiplexed Forward Packet Data Pilot Channels, one per transmission antenna, is needed. The continuous Forward Pilot Channel is still used by all mobile stations for initial acquisition, phase recovery, timing recovery and handoffs. The Packet Data Pilot Subchannel within the FPDCH provides the mobile stations with additional means of predicting the received C/I from each antenna accurately for the purpose of access terminal initiated forward data rate and antenna indication (RAI) of the data channel transmission. Each mobile station, using both the Forward Packet Data Subchannels and/or the continous Pilot Channel, predicts the received C/I at a rate of 800 Hz. The set of continuous and past C/I values are then used to predict a maximum forward link transmission rate that the mobile station can handle. The mobile station also uses the rate of change within the C/I values to predict which transmission antenna scheme is best suited for its forward link. The data rate and antenna information are then transmitted by each mobile station at a rate of 800 Hz [4]. The mobile station performs scheduling and asynchronous incremental operation on the scheduled mobile station based on the RAI values. Every supported RAI rate has both a long and a short encoder packet format. The base station decides which mode to use.

The Forward Packet Data Pilot Subchannel is transmitted at the full power allocated to the FPDCH at a given time.

3.2 Forward Packet Data Preamble Subchannel

The Forward Packet Data Traffic Subchannel is a packet-based, variable-rate channel. The user data for a mobile station is transmitted at a data rate that varies from 9.6 kbps to 6.144 Mbps (with MIMO) or 3.072 Mbps (without MIMO).

The Forward Traffic Subchannel data is encoded in blocks called encoder packets. Prior to each encoder packet, the Forward Packet Data Preamble Subchannel is transmitted. The size of the preamble depends on the rate of the FPDCH.

The preamble is a QPSK modulated channel that has all-'0' symbols sent on the in-phase channel. The in-phase signal is covered by a 32-chip bi-orthogonal sequence and the sequence is repeated several times depending on the RAI rate. The bi-orthogonal sequence is specified in terms of the 32-ary Walsh functions and their bit-by-bit complements by

$$W_{i/2}^{32} \text{ for } i = 0, 2, \ldots, 62$$
$$\overline{W_{(i-1)/2}^{32}} \text{ for } i = 1, 3, \ldots, 63$$

where i = 0, 1,..., 63 is the MAC index and $\overline{W_i^{32}}$ is the bit-by-bit complement of the 32-chip Walsh function of order i.

The 32-chip preamble repetition factors are specified in Table 3.1 and Table 3.2 for each RAI rate in non-MIMO and MIMO configurations, respectively.

Table 3.1 Preamble Repetition for the Non-MIMO Rates

RAI Rate (kbps)	32-Chip Preamble Sequence Repetition	Preamble Chips per Encoder Sub-Packet
9.6	128	4096
19.2	64	2048
38.4	32	1024
76.8	16	512
153.6	8	256
307.2	4	128
614.4	2	64
1228.8	2	64
921.6	2	64
1843.2	2	64
1228.8	2	64
2457.6	2	64
1536.0	2	64
3072.0	2	64

Table 3.2 Preamble Repetition for the MIMO Rates

RAI Rate (kbps)	32-Chip Preamble Sequence Repetition	Preamble Chips per Encoder Sub-Packet
614.4	2	64
1228.8	2	64
2457.6	2	64
768.0	2	64
1536.0	2	64
3072.0	2	64
921.6	2	64
1843.2	2	64
3686.4	2	64
1228.8	2	64
2457.6	2	64
4915.2	2	64
1536.0	2	64
3072.0	2	64
6144.0	2	64

The quadrature component of the preamble consists of 1-bit New/Continued Frame Indicator for Incremental Redundancy operation, 1-bit Short/Long Encoder Packet Format Indicator and 2-bits Sub-packet Sequence Number. These bits are multiplexed, encoded, repeated and covered by the same bi-orthogonal Walsh code that represents the MAC ID of the user. The number of repetitions varies from rate to rate so that the number of chips in the quadrature component of the preamble is equal to the number of chips in the in-phase component. The details of the encoding algorithm and the number of repetitions are TBD.

3.3 Forward Packet Data Traffic Subchannel

In the Forward Packet Data Traffic Subchannel, each encoder packet is encoded scrambled and then fed into a QPSK/8-PSK/16-QAM modulator. The modulated symbols are block interleaved, and the resulting sequences are repeated or punctured as necessary. The exact repetition/puncturing levels depend on the current transmission rate, current RAI rate as well as the current Walsh space allocated to the FPDCH. The resulting sequences of modulation symbols are demultiplexed to form a number of pairs (in-phase and quadrature) of parallel streams. The exact number of pairs is variable, and depends on the number of code channels that are currently being used by the other forward CDMA channels defined in Table 2.1 [5]. The base station, at regular intervals,

transmits the available Walsh space for the FPDCH to the mobile stations on the Forward Packet Data MAC Channel. The FPDCH uses a number of orthogonal Walsh functions selected from potentially different Walsh alphabets.

Each one of the parallel streams of the FPDCH is covered with a distinct 16-ary/32-ary/64-ary/128-ary Walsh function at a chip rate to yield Walsh symbols at 76.8 ksps/38.4 ksps/19.2 ksps/9.6 ksps. The Walsh-coded symbols of all the streams are summed together to form a single in-phase stream and a single quadrature stream at chip rates of 1.2288 Mcps. The resulting chips are time-division multiplexed with the preamble, and pilot subchannel chips to form the resultant sequence of chips for the quadrature spreading operation.

Forward Packet Data Traffic Subchannel encoder packets can be transmitted in 1 to 64 slots (see Table 3.1 and Table 3.2). For each RAI rate, the encoder packets are divided into 1, 2 or 4 sub-packets. When a user is scheduled to be serviced on the FPDCH, rather than sending the entire encoder packet to the mobile station at an effective rate that is equal to the RAI rate, the base station initially transmits only the first sub-packet. In this case, in the preamble, the Sub-Packet Sequence Number is set to '00'. The sub-packet is preceded by the preamble whose length is dictated by the RAI rate. If the mobile station detects the preamble and succeeds in decoding the sub-packet, transmission is successful and the mobile station sends an ACK back. The effective rate of the mobile station in this case is equal to the number of sub-packets times the RAI rate. If the mobile station detects the preamble but is not successful in decoding the sub-packet, it sends a NACK back. In this case, the next sub-packet is transmitted by the base station the next time the mobile station is scheduled for service. Then, the Sub-Packet Sequence Number is set to '01' . Due to the asynchronous nature of the incremental redundancy operation, every sub-packet needs to be preceded by a preamble. The preamble gives the mobile station information the sequence number of the sub-packet. During the course of the incremental redundancy operation, each sub-packet may be received with a different preamble size since this value is completely dictated by the current RAI rate. In the incremental redundancy operation, if the user is not able to detect/decode the preamble, it sends neither an ACK nor a NACK.

The set of rates signaled by the RAI channel, their corresponding slot and sub-slot structures as well as the encoder packet coding and modulation types are listed in Table 3.3 for Non-MIMO configurations and in Table 3.4 for MIMO configurations, respectively.

The overall Forward Packet Data Channel structure is shown in Figure 3.3 for base stations with a single transmit antenna. Similarly, the Forward Packet Data Channel structure for base stations with multiple transmit antennas capable of performing STD and MIMO is shown in Figure 3.4.

Table 3.3 Set of Rates Signaled by the RAI Channel for the Non-MIMO modes of operation

			Short Format		Long Format			
RAI Rate (kbps)	Starting Rate (kbps)	Number of Sub-packets	Number of Slots per Sub-packet	Bits per Encoder Packet	Number of Slots per Sub-packet	Bits per Encoder Packet	Code Rate	Modulation Type
9.6	38.4	4	8	384	16	768	1/5	QPSK
19.2	76.8	4	4	384	8	768	1/5	QPSK
38.4	153.6	4	2	384	4	768	1/5	QPSK
76.8	307.2	4	2	768	4	1536	1/5	QPSK
153.6	614.4	4	1	768	2	1536	1/3	QPSK
307.2	1228.8	4	1	1536	2	3072	1/3	QPSK
614.4	1228.8	2	1	1536	2	3072	1/3	QPSK
1228.8	1228.8	1	1	1536	2	3072	1/3	QPSK
921.6	1843.2	2	1	2304	2	4608	1/3	8-PSK
1843.2	1843.2	1	1	2304	2	4608	1/3	8-PSK
1228.8	2457.6	2	1	3072	2	6144	1/3	16-QAM
2457.6	2457.6	1	1	3072	2	6144	1/3	16-QAM
1536	3072	2	1	3840	2	7680	1/2	16-QAM
3072	3072	1	1	3840	2	7680	1/2	16-QAM

Table 3.4 Set of Rates Signaled by the Rate and Antenna Indicator Channel for the MIMO mode of operation

			Short Format		Long Format			
RAI Rate (kbps)	Starting Rate (kbps)	Number of Sub-packets	Number of Slots per Sub-packet	Bits per Encoder Packet	Number of Slots per Sub-packet	Bits per Encoder Packet	Code Rate	Modulation Type
614.4	2457.6	4	1	3072	2	6144	1/3	QPSK
1228.8	2457.6	2	1	3072	2	6144	1/3	QPSK
2457.6	2457.6	1	1	3072	2	6144	1/3	QPSK
768	3072	4	1	3840	2	7680	1/2	QPSK
1536	3072	2	1	3840	2	7680	1/2	QPSK
3072	3072	1	1	3840	2	7680	1/2	QPSK
921.6	3686.4	4	1	4608	2	9216	1/3	8-PSK
1843.2	3686.4	2	1	4608	2	9216	1/3	8-PSK
3686.4	3686.4	1	1	4608	2	9216	1/3	8-PSK
1228.8	4915.2	4	1	6144	2	12288	1/3	16-QAM
2457.6	4915.2	2	1	6144	2	12288	1/3	16-QAM
4915.2	4915.2	1	1	6144	2	12288	1/3	16-QAM
1536	6144	4	1	7680	2	15360	1/2	16-QAM
3072	6144	2	1	7680	2	15360	1/2	16-QAM
6144	6144	1	1	7680	2	15360	1/2	16-QAM

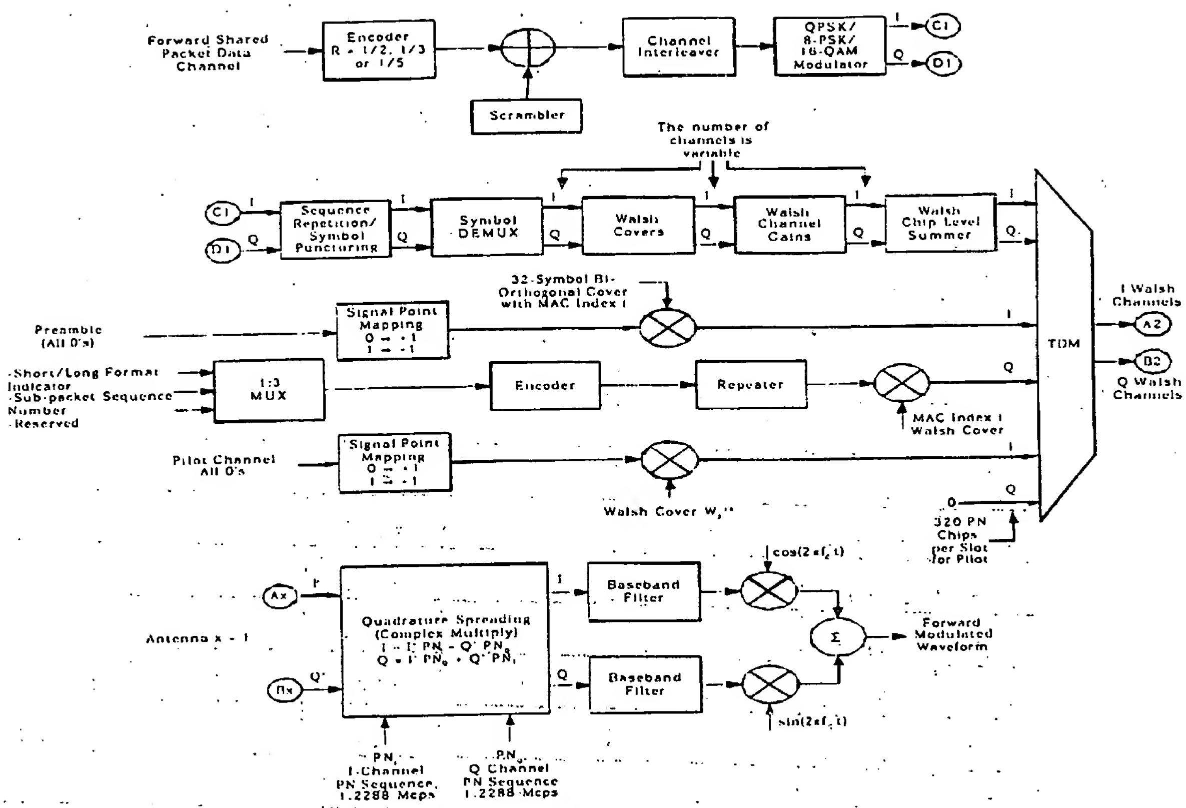


Figure 3.3 FPDCH Structure for Base Stations with 1 Transmit Antenna

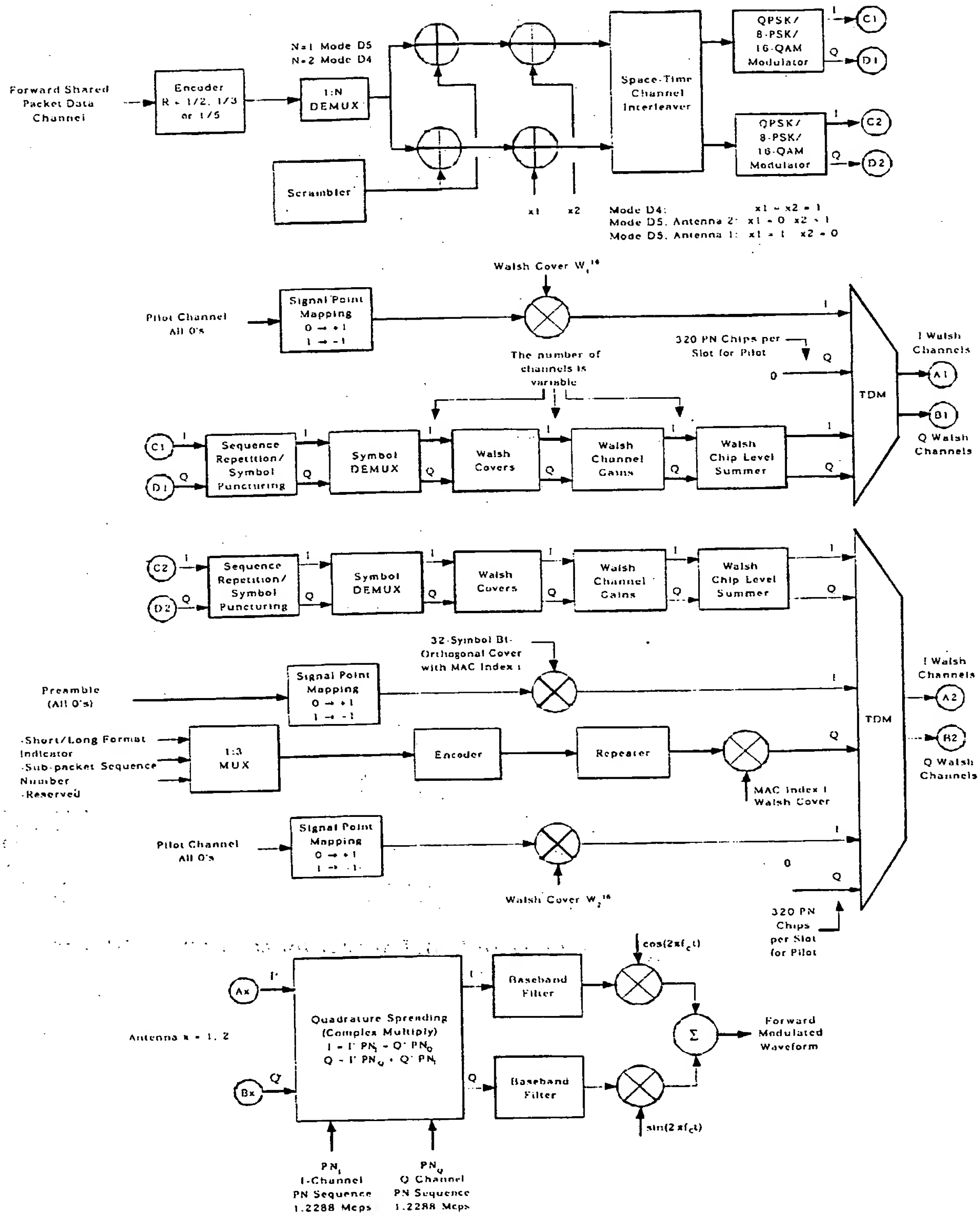
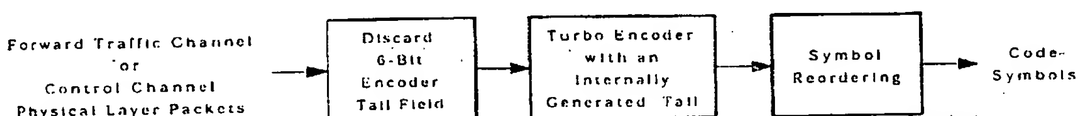


Figure 3.4 FPDCH Structure for Base Stations with 2 Transmit Antennas

3.3.1 Forward Packet Data Traffic Subchannel Encoding

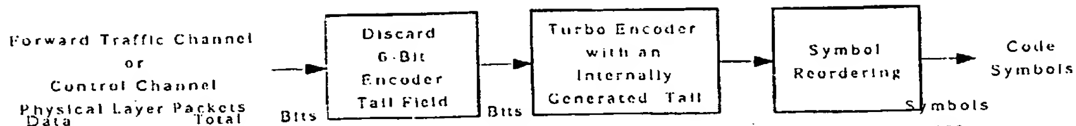
The Traffic Channel Physical Layer packets are encoded with code rates of R = 1/2, 1/3 or 1/5. The encoder discards the 6-bit TAIL field of the encoder packet inputs, encode the remaining bits with a parallel turbo encoder, and reorder the turbo encoder output symbols. During encoding, an encoder output tail sequence is added. If the number of bits into the turbo encoder after the 6-bit encoder packet TAIL field is discarded is N_{turbo}, the turbo encoder generates N_{turbo}/R encoded data output symbols followed by 6/R tail output symbols, where R is the code rate of 1/2, 1/3, or 1/4. The turbo encoder employs two systematic, recursive, convolutional encoders connected in parallel, with an interleaver, the turbo interleaver, preceding the second recursive convolutional encoder. The two recursive convolutional codes are called the constituent codes of the turbo code. The outputs of the constituent encoders are punctured and repeated to achieve the $(N_{turbo} + 6)/R$ output symbols.

Figure 3.5 and Figure 3.6 illustrate the forward link encoding approach for the Non-MIMO and MIMO rates, respectively.



Data Rate (kbps)	Slots Used	Total Code Rate	Bits per Packet	Bits per Packet	Symbols per Packet
9.6	32/64	1/5	384/768	378/762	1920/3840
19.2	16/32	1/5	384/768	378/762	1920/3840
38.4	8/16	1/5	384/768	378/762	1920/3840
76.8	8/16	1/5	768/1536	762/1530	3840/7680
153.6	4/8	1/3	768/1536	762/1530	2304/4608
307.2	4/8	1/3	1536/3072	1530/3066	4608/9216
614.4	2/4	1/3	1536/3072	1530/3066	4608/9216
1,228.8	1/2	1/3	1536/3072	1530/3066	4608/9216
921.6	2/4	1/3	2304/4608	2298/4602	6912/13824
1,843.2	1/2	1/3	2304/4608	2298/4602	6912/13824
1,228.8	2/4	1/3	3072/6144	3066/6138	9216/18432
2,457.6	1/2	1/3	3072/6144	3066/6138	9216/18432
1,536.0	2/4	1/2	3840/7680	3834/7674	7680/15360
3,072.0	1/2	1/2	3840/7680	3834/7674	7680/15360

Figure 3.5 Forward Link Encoder for the Non-MIMO rates



Data Rate (kbps)	Slots Used	Total Code Rate	Bits per Packet	Bits per Packet	Symbols per Packet
614.4	4/8	1/3	3072/6144	3066/6138	9216/18432
1.228.8	2/4	1/3	3072/6144	3066/6138	9216/18432
2.457.6	1/2	1/3	3072/6144	3066/6138	9216/18432
768.0	4/8	1/2	3840/7680	3834/7674	7680/15360
1.536.0	2/4	1/2	3840/7680	3834/7674	7680/15360
3,072.0	1/2	1/2	3840/7680	3834/7674	7680/15360
921.6	4/8	1/3	4608/9216	4602/9210	13824/27648
1,843.2	2/4	1/3	4608/9216	4602/9210	13824/27648
3,686.2	1/2	1/3	4608/9216	4602/9210	13824/27648
1.228.8	4/8	1/3	6144/12288	6138/12282	18432/36864
2.457.6	2/4	1/3	6144/12288	6138/12282	18432/36864
4.915.2	1/2	1/3	6144/12288	6138/12282	18432/36864
1,536.0	4/8	1/2	7680/15360	7674/15354	15360/30720
3.072.0	2/4	1/2	7680/15360	7674/15354	15360/30720
6.144.0	1/2	1/2	7680/15360	7674/15354	15360/30720

Figure 3.6 Forward Link Encoder for the MIMO rates

A common constituent code is used for the turbo codes of rate 1/2, 1/3, and 1/5. The transfer function for the constituent code is set to be

$$G(D) = \begin{bmatrix} 1 & \frac{n_0(D)}{d(D)} & \frac{n_1(D)}{d(D)} \end{bmatrix}$$

where $d(D) = 1 + D^2 + D^3$, $n_0(D) = 1 + D + D^3$, and $n_1(D) = 1 + D + D^2 + D^3$.

The turbo encoder generates an output symbol sequence that is identical to the one generated by the encoder shown in Figure 3.7. Initially, the states of the constituent encoder registers in this figure are set to zero. Then, the constituent encoders are clocked with the switches in the positions noted.

The encoded data output symbols are generated by clocking the constituent encoders N_{turbo} times with the switches in the up positions and puncturing the outputs as specified in Table 3.5. Within a puncturing pattern, a '0' means that the symbol shall be deleted and a '1' means that the symbol shall be passed. The constituent encoder outputs for each bit period shall be output in the sequence X, Y_0, Y_1, X', Y'_0, Y'_1 with the X output first. Symbol repetition is not used in generating the encoded data output symbols.

The turbo encoder generates 6/R tail output symbols following the encoded data output symbols. This tail output symbol sequence is identical to the one generated by the encoder shown in Table 3.6. The tail output symbols are generated after the constituent encoders have been clocked N_{turbo} times with the switches in the up position. The first 3/R tail output symbols are generated by clocking Constituent Encoder 1 three times with its switch in the down position while Constituent Encoder 2 is not clocked and puncturing and repeating the resulting constituent encoder output symbols. The last 3/R tail output symbols are generated by clocking Constituent Encoder 2 three times with its switch in the down position while Constituent Encoder 1 is not clocked and puncturing and repeating the resulting constituent encoder output

symbols. The constituent encoder outputs for each bit period are output in the sequence X, Y_0, Y_1, X', Y'_0, Y'_1 with the X output first.

The constituent encoder output symbol puncturing for the tail symbols are as specified in Table 3.6. Within a puncturing pattern, a '0' means that the symbol will be deleted and a '1' means that a symbol will be passed. For rate 1/2 turbo codes, the tail output symbols for each of the first three tail bit periods are XY_0, and the tail output symbols for each of the last three tail bit periods are $X'Y'_0$. For rate 1/3 turbo codes, the tail output symbols for each of the first three tail bit periods are XXY_0, and the tail output symbols for each of the last three tail bit periods are $X'X'Y'_0$. For rate 1/5 turbo codes, the tail output symbols for each of the first three tail bit periods are $XXY_0Y_1Y_1$, and the tail output symbols for each of the last three tail bit periods shall be $XX'Y'_0Y'_1Y'_1$.

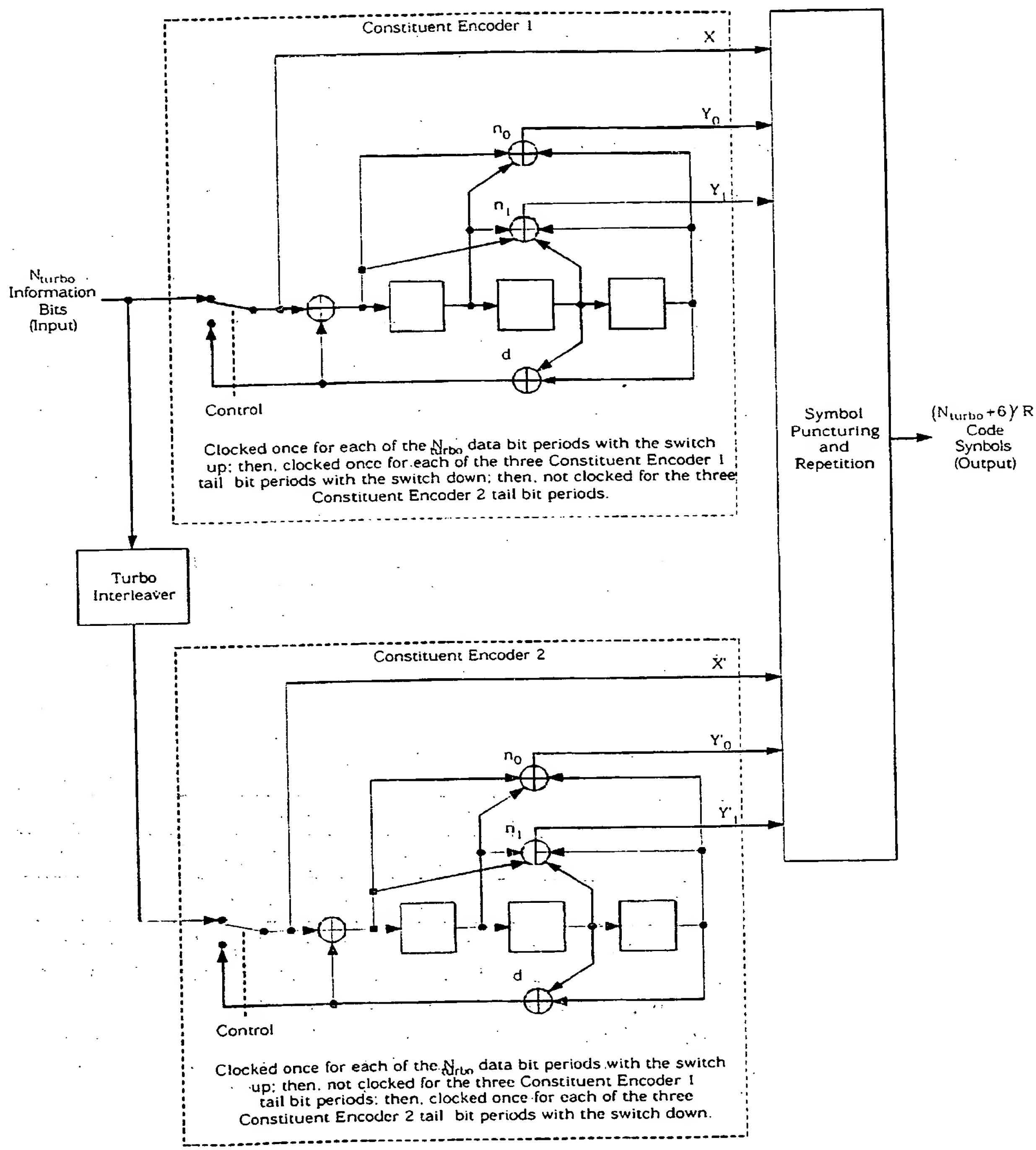


Figure 3.7 Turbo Encoder

Table 3.5 Puncturing Patterns for the Data Bit Periods

	Code Rates		
Output	**1/2**	**1/3**	**1/5**
X	11	11	11
Y_0	10	11	11
Y_1	00	00	11
X'	00	00	00
Y'_0	01	11	11
Y'_1	00	00	11

Note: For each rate, the puncturing table is to be read first from top to bottom and then from left to right.

Table 3.6 Puncturing Patterns for the Tail Bit Periods

	Code Rates		
Output	**1/2**	**1/3**	**1/5**
X	111 000	111 000	111 000
Y_0	111 000	111 000	111 000
Y_1	000 000	000 000	111 000
X'	000 111	000 111	000 111
Y'_0	000 111	000 111	000 111
Y'_1	000 000	000 000	000 111

Note: For rate-1/2 turbo codes, the puncturing table is to be read from top to bottom and then from left to right. For rate-1/3 turbo codes, the puncturing table is to be read first from top to bottom repeating X and X', and then from left to right. For rate-1/5 turbo codes, the puncturing table shall be read first from top to bottom repeating X, X', Y_1, and Y'_1 and then from left to right.

The turbo interleaver, which is part of the turbo encoder, block interleaves the turbo encoder input data.

The turbo interleaver should be functionally equivalent to an approach where the entire sequence of turbo interleaver input bits are written sequentially into an array at a sequence of addresses, and then the entire sequence is read out from a sequence of addresses that are defined by the procedure described below.

Let the sequence of input addresses be from 0 to N_{turbo} - 1. Then, the sequence of interleaver output addresses is equivalent to those generated by the procedure illustrated in Figure 3.8. and described below.[1]

1. Determine the turbo interleaver parameter, n, where n is the smallest integer such that $N_{turbo} \le 2^{n+5}$. Table 3.7 gives this parameter for the numbers of bits per frame that are available without flexible data rates.

2. Initialize an (n + 5)-bit counter to 0.

3. Extract the n most significant bits (MSBs) from the counter and add one to form a new value. Then, discard all except the n least significant bits (LSBs) of this value.

4. Obtain the n-bit output of the table lookup defined in Table 3.8 with a read address equal to the five LSBs of the counter. Note that this table depends on the value of n.

5. Multiply the values obtained in Steps 3 and 4, and discard all except the n LSBs.

6. Bit-reverse the five LSBs of the counter.

7. Form a tentative output address that has its MSBs equal to the value obtained in Step 6 and its LSBs equal to the value obtained in Step 5.

8. Accept the tentative output address as an output address if it is less than N_{turbo}; otherwise, discard it.

9. Increment the counter and repeat Steps 3 through 8 until all N_{turbo} interleaver output addresses are obtained.

---

[1] This procedure is equivalent to one where the counter values are written into a 2^5-row by 2^n-column array by rows, the rows are shuffled according to a bit-reversal rule, the elements within each row are permuted according to a row-specific linear congruential sequence, and tentative output addresses are read out by column. The linear congruential sequence rule is $x(i + 1) = (x(i) + c) \bmod 2^n$, where $x(0) = c$ and c is a row-specific value from a table lookup.

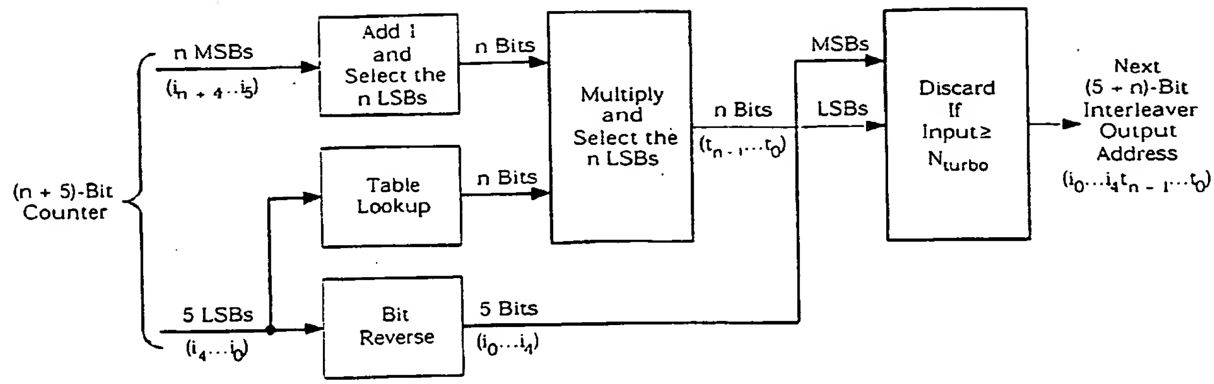


Figure 3.8 Turbo Interleaver Output Address Calculation Procedure

Table 3.7 Turbo Interleaver Parameter

Physical Layer Packet Size	Turbo Interleaver Block Size N_{turbo}	Turbo Interleaver Parameter n
384	378	4
768	762	5
1536	1530	6
2304	2298	7
3072	3066	7
3840	3834	7
4608	4602	8
6144	6138	8
7680	7674	8
9216	9210	9
12288	12282	9
15360	15354	9

Table 3.8 Turbo Interleaver Lookup Table Definition

Table Index	n = 4 Entries	n = 5 Entries	n = 6 Entries	n = 7 Entries	n = 8 Entries	n = 9 Entries
0	5	27	3	15	3	13
1	15	3	27	127	1	335
2	5	1	15	89	5	87
3	15	15	13	1	83	15
4	1	13	29	31	19	15
5	9	17	5	15	179	1
6	9	23	1	61	19	333
7	15	13	31	47	99	11
8	13	9	3	127	23	13
9	15	3	9	17	1	1
10	7	15	15	119	3	121
11	11	3	31	15	13	155
12	15	13	17	57	13	1
13	3	1	5	123	3	175
14	15	13	39	95	17	421
15	5	29	1	5	1	5
16	13	21	19	85	63	509
17	15	19	27	17	131	215
18	9	1	15	55	17	47
19	3	3	13	57	131	425
20	1	29	45	15	211	295
21	3	17	5	41	173	229
22	15	25	33	93	231	427
23	1	29	15	87	171	83
24	13	9	13	63	23	409
25	1	13	9	15	147	387
26	9	23	15	13	243	193
27	15	13	31	15	213	57
28	11	13	17	81	189	501
29	3	1	5	57	51	313
30	15	13	15	31	15	489
31	5	13	33	69	67	391

The turbo encoder data and tail output symbols generated with the rate-1/5 encoder are reordered according to the following procedure:

1. All of the data and tail turbo encoder output symbols are demultiplexed into five sequences denoted U, V_0, V_1, V'_0, and V'_1. The encoder output symbols are sequentially distributed from the U sequence to the V_1 sequence with the first encoder output symbol

going to the U sequence, the second to the V_0 sequence, the third to the V_1 sequence, the fourth to the V'_0 sequence, the fifth to the V'_1 sequence, the sixth to the U sequence, etc.

2. The U, V_0, V_1, V'_0, and V'_1 sequences are ordered according to $UV_0V'_0V_1V'_1$. That is, the U sequence of symbols is first and the V'_1 sequence of symbols is last.

The turbo encoder data and tail output symbols generated with the rate-1/3 encoder are reordered according to the following procedure:

1. All of the data and tail turbo encoder output symbols are demultiplexed into three sequences denoted U, V_0, and V'_0. The encoder output symbols are sequentially distributed from the U sequence to the V'_0 sequence with the first encoder output symbol going to the U sequence, the second to the V_0 sequence, the third to the V'_0 sequence, the fourth to the U sequence, etc.

2. The U, V_0, and V'_0 sequences are ordered according to $UV_0V'_0$. That is, the U sequence of symbols is first and the V'_0 sequence of symbols is last.

The turbo encoder data and tail output symbols generated with the rate-1/2 encoder is reordered according to the following procedure:

1. All of the data and tail turbo encoder output symbols are demultiplexed into two sequences denoted U and V_0. The encoder output symbols are be sequentially distributed from the U sequence to the V_0 sequence with the first encoder output symbol going to the U sequence, the second to the V_0 sequence, the third to the U sequence, etc.

2. The U, and V_0 sequences are ordered according to UV_0. That is, the U sequence of symbols is first and the V_0 sequence of symbols is last.

Table 3.9 gives the order of the symbols out of the turbo encoder and their mapping to demultiplexer output sequences.

Table 3.9 Turbo Encoder Output and Symbol Reordering Demultiplexer Symbol Sequences

Type of Sequence	Symbol Sequence		
	R = 1/5	R = 1/3	R= 1/2
Turbo Encoder Data Output Sequence	$X\ Y_0\ Y_1\ Y'_0\ Y'_1$	$X\ Y_0\ Y'_0$	$X\ Y_0$
Turbo Encoder Constituent Encoder 1 Tail Output Sequence	$X\ X\ Y_0\ Y_1\ Y_1$	$X\ X\ Y_0$	$X\ Y_0$
Turbo Encoder Constituent Encoder 2 Tail Output Sequence	$X'\ X'\ Y'_0\ Y'_1\ Y'_1$	$X'\ X'\ Y'_0$	$X'Y'_0$
Demultiplexer Output Sequence Mapping	$U\ V_0\ V_1\ V'_0\ V'_1$	$U\ V_0\ V'_0$	UV_0

The output of the encoder is scrambled to randomize the data prior to modulation to limit the peak-to-average ratio of the envelope of the modulated waveform. The details of the scrambling operation is TBD.

3.3.2 Forward Packet Data Traffic Subchannel Channel Interleaving

The symbols input to the interleaver are written sequentially at addresses 0 to the block size (N) minus one. The interleaved symbols are read out in permuted order from address A_i, as follows:

$$A_i = 2^m(i \bmod J) + BRO_m(\lfloor i/J \rfloor)$$

where

$i = 0$ to $N - 1$,

m and J are the interleaver parameters, and

$\lfloor x \rfloor$ indicates the largest integer less than or equal to x, and

$BRO_m(y)$ indicates the bit-reversed m-bit value of y (i.e., $BRO_3(6) = 3$). The specific values of m and J for each encoder packet size are TBD.

3.3.3 Forward Packet Data Traffic Subchannel Modulation

The output of the channel interleaver is applied to a modulator that outputs an in-phase stream and a quadrature-stream of modulated values. The modulator generates QPSK, 8-PSK, or 16-QAM modulation symbols, depending on the data rate.

3.3.3.1 QPSK Modulation

When the transmission antenna scheme employed is non-MIMO, for encoder packet sizes of 768, 1536 or 3072 bits, and when the transmission antenna scheme employed is MIMO, for encoder packet sizes of 6144 or 7680 bits, two successive interleaver

output symbols are grouped to form QPSK modulation symbols. Each group of two adjacent interleaver output symbols, x(2i) and x(2i + 1), i = 0,..., N, N= 383, 767 or 1535 for Non-MIMO and N= 3071 or 6143 for MIMO, are mapped into a complex modulation symbol ($m_I(i)$, $m_Q(i)$) as specified in Table 3.10. Figure 3.9 shows the signal constellation of the QPSK modulator, where s_0 = x(2k) and s_1 = x(2k + 1).

Table 3.10 QPSK Modulation Table

Interleaved Symbols		Modulation Symbols	
s_1 x(2k + 1)	s_0 x(2k)	$m_I(k)$	$m_Q(k)$
0	0	D	D
0	1	-D	D
1	0	D	-D
1	1	-D	-D

Note: $D = 1/\sqrt{2}$.

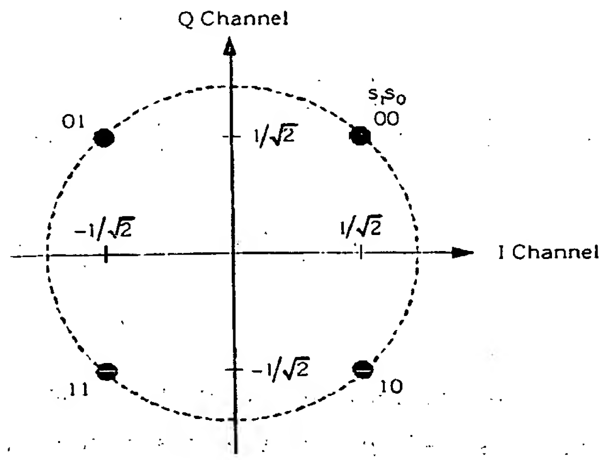


Figure 3.9 Signal Constellation for QPSK Modulation

3.3.3.2 8-PSK Modulation

When the transmission antenna scheme employed is non-MIMO, for encoder packet sizes of 4608 bits, and when the transmission antenna scheme employed is MIMO, for encoder packet sizes of 9216 bits three successive interleaver output symbols are grouped to form 8-PSK modulation symbols. Each group of three adjacent interleaver output symbols, x(3i), x(3i + 1), and x(3i + 2), i = 0,..., N, N= 2303 for non-MIMO and N= 4607 for MIMO, shall be mapped into a complex modulation symbol ($m_I(i)$, $m_Q(i)$) as

specified in Table 3.11. Figure 3.10 shows the signal constellation of the 8-PSK modulator, where $s_0 = x(3k)$, $s_1 = x(3k + 1)$, and $s_2 = x(3k + 2)$.

Table 3.11 8-PSK Modulation Table

Interleaved Symbols			**Modulation Symbols**	
s_2 $x(3k + 2)$	s_1 $x(3k + 1)$	s_0 $x(3k)$	$m_I(k)$	$M_Q(k)$
0	0	0	C	S
0	0	1	S	C
0	1	1	-S	C
0	1	0	-C	S
1	1	0	-C	-S
1	1	1	-S	-C
1	0	1	S	-C
1	0	0	C	-S

Note: $C = \cos(\pi/8) \approx 0.9239$ and $S = \sin(\pi/8) = 0.3827$.

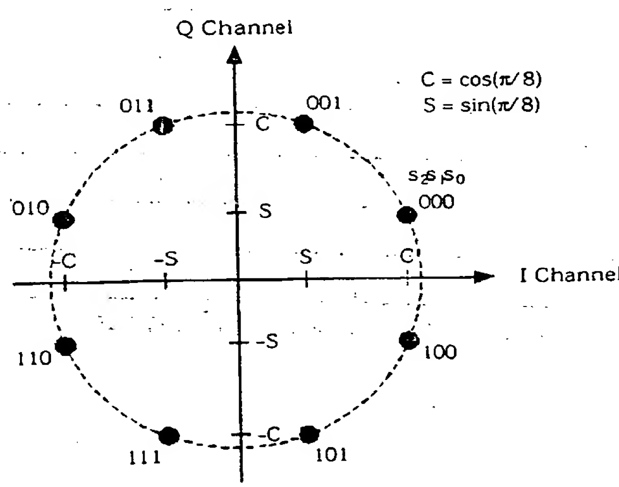


Figure 3.10 Signal Constellation for 8-PSK Modulation

3.3.3.3 16-QAM Modulation

When the transmission antenna scheme employed is non-MIMO, for encoder packet sizes of 6144 or 7680 bits, and when the transmission antenna scheme employed is MIMO, for encoder packet sizes of 12288 or 15360 bits, four successive interleaver output symbols are grouped to form 16-QAM modulation symbols. Each group of four adjacent interleaver output symbols, $x(4i)$, $x(4i + 1)$, $x(4i + 2)$, and $x(4i + 3)$, $i = 0, \ldots, N$, $N = 3071$ or 6143 for non-MIMO and $N = 6143$ or 7679 for MIMO, are mapped into a

complex modulation symbol ($m_I(i)$, $m_Q(i)$) as specified in Table 3.12. Figure 3.11 shows the signal constellation of the 16QAM modulator, where $s_0 = x(4k)$, $s_1 = x(4k + 1)$, $s_2 = x(4k + 2)$, and $s_3 = x(4k + 3)$.

Table 3.12 16-QAM Modulation Table

Interleaved Symbols				**Modulation Symbols**	
s_3 **x(4k + 3)**	s_2 **x(4k + 2)**	s_1 **x(4k + 1)**	s_0 **x(4k)**	$m_Q(k)$	$m_I(k)$
0	0	0	0	B	B
0	0	0	1	B	A
0	0	1	1	B	-A
0	0	1	0	B	-B
0	1	0	0	A	B
0	1	0	1	A	A
0	1	1	1	A	-A
0	1	1	0	A	-B
1	1	0	0	-A	B
1	1	0	1	-A	A
1	1	1	1	-A	-A
1	1	1	0	-A	-B
1	0	0	0	-B	B
1	0	0	1	-B	A
1	0	1	1	-B	-A
1	0	1	0	-B	-B

Note: $A = 1/\sqrt{10} \approx 0.3162$ and $B = 3/\sqrt{10} \approx 0.9487$.

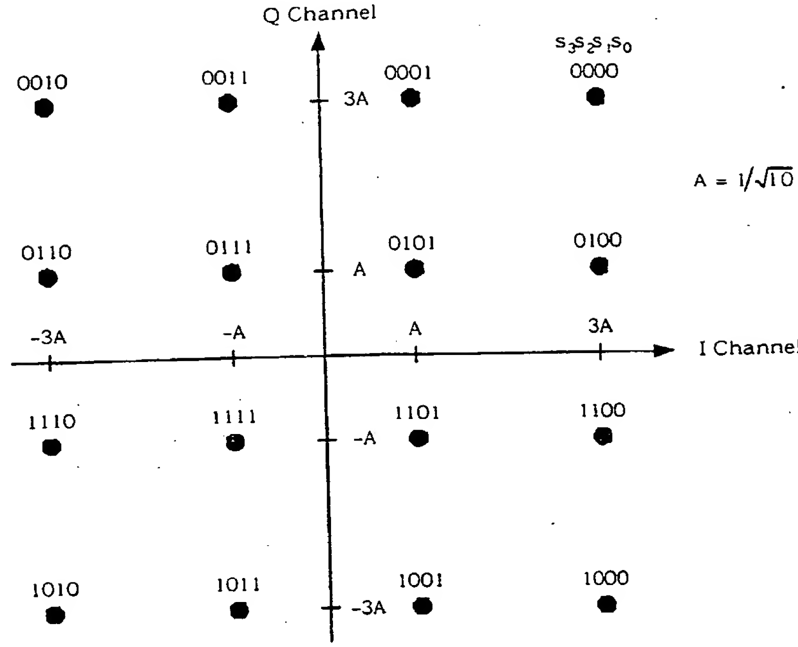


Figure 3.1 1 Signal Constellation for 16-QAM Modulation

3.3.4 Forward Packet Data Traffic Subchannel Sequence Repetition and Symbol Puncturing

Based on the transmission rate and the corresponding encoder sub-packet size as well as the size of the preamble in use, the number of modulation symbols that the modulator provides per encoder sub-packet and the number of modulation symbols needed for the data portion of the allocated slots are calculated. If the number of required modulation symbols is more than the number provided, the sequence of input modulation symbols are repeated as many full-sequence times as possible followed by a partial transmission if necessary. If a partial transmission is needed, the first portion of the input modulation symbol sequence is used. If the number of required modulation symbols is less than the number provided, only the first portion of the input modulation symbol sequence is used. The number of full repetitions, number of modulation symbols in the last partial transmission and the number of punctured symbols all depend on the size of the preamble in use as well the Walsh alphabets and the corresponding code channels that the Forward Packet Data Channel Uses. For a given rate, numerous possibilities of symbol repetitions or puncturing are possible. All possible sequence repetition and symbol puncturing parameters as a function of the preamble size and Walsh space used by the channels of the circuit switched service have been specified for all supported data rates of 38.4 kbps-2.457.6 kbps. These tables will be provided subsequently.

The individual streams generated by the symbol demultiplexer are assigned to a distinct Walsh channel. The Walsh codes will be selected from the Walsh space that is not in use by the code channels of the circuit switched data service.

The modulated symbols on each branch of each Walsh channel are scaled to maintain a constant total transmit power independent of data rate. The gain settings are normalized to a unity reference equivalent to unmodulated BPSK transmitted at full power.

The scaled Walsh chips associated with the parallel Walsh channels are summed on a chip-by-chip basis.

The FPDCH data modulation chips are time-division multiplexed (TDM'd) with the preamble, and the Pilot subchannel chips according to the parameters specified earlier.

The Walsh chip rate is fixed at 1.2288 Mcps.

Following orthogonal spreading, the combined modulation sequence is quadrature spread as shown in Figures 3.3 and 3.4. The spreading sequence is a quadrature sequence of length 2^{15} (i.e., 32768 PN chips in length). This sequence is based on the following characteristic polynomials:

$$P_I(x) = x^{15} + x^{10} + x^8 + x^7 + x^6 + x^2 + 1$$

(for the in-phase (I) sequence)

and

$$P_Q(x) = x^{15} + x^{12} + x^{11} + x^{10} + x^9 + x^5 + x^4 + x^3 + 1$$

(for the quadrature-phase (Q) sequence).

The maximum length linear feedback shift-register sequences {I(n)} and {Q(n)} based on the above polynomials are of length $2^{15} - 1$ and can be generated by the following linear recursions:

$$I(n) = I(n-15) \oplus I(n-13) \oplus I(n-9) \oplus I(n-8) \oplus I(n-7) \oplus I(n-5)$$

(based on $P_I(x)$ as the characteristic polynomial)

and

$$Q(n) = Q(n-15) \oplus Q(n-12) \oplus Q(n-11) \oplus Q(n-10) \oplus Q(n-6) \oplus Q(n-5) \oplus Q(n-4) \oplus Q(n-3)$$

(based on $P_Q(x)$ as the characteristic polynomial),

where I(n) and Q(n) are binary valued ('0' and '1') and the additions are modulo-2. In order to obtain the I and Q pilot PN sequences (of period 2^{15}), a '0' is inserted in the {I(n)} and {Q(n)} sequences after 14 consecutive '0' outputs (this occurs only once in each period). Therefore, the pilot PN sequences have one run of 15 consecutive '0' outputs instead of 14.

The chip rate for the PN sequence is 1.2288Mcps.

4 FORWARD PACKET DATA MAC CHANNEL

The Forward Packet Data MAC Channel (MACH) is a code division multiplexed broadcast message aiding the operation of packet data mobile stations within the

FPDCH. A predefined Walsh code from the code space of Walsh-128 is allocated for the MACH.

The MACH consists of 4 subchannels: Reverse Activity (RA) Subchannel, FPDCH Walsh Space Indicator (WSI) Subchannel, FPDCH Power Fraction Information (PFI) Subchannel, and the Forward Link Activity Subchannel (FAC) as seen in Figure 4.1. The MACH is a QPSK modulated channel, with the RA and WSI transmitted on the in-phase component every 20 ms. The quadrature component has the PFI and FAC transmitted every 1.25 ms.

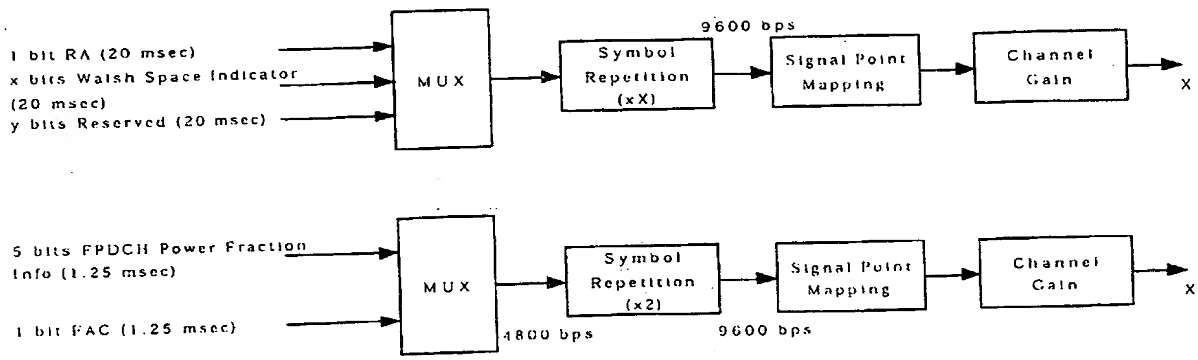


Figure 4.1. Forward Packet Data MAC Channel Structure

The RA and FAC are as described in the 1xEV-DO standard.

The FPDCH Power Fraction indicates the ratio of the power allocated to the rate controlled packet data operation to the total base station transmission power at time of transmission.

The Walsh space indicator specifies the details of the code space allocated to the operation of the rate controlled packet data service.

5 FORWARD COMMON POWER CONTROL CHANNEL

The Common Power Control Channel already exists in 3G 1x. However, a new channel configuration needs to be defined to satisfy the proper operation of the 1xEV-DV as shown in Figure 5.1. The power control bits to the packet data users are sent at a rate of 1.25 ms on this channel. The bits for different users are time multiplexed and the relative offsets of the power control bits are assigned according to the MAC Ids of the individual users. Power control information to 16, 32 and 64 mobile stations are supported using codes from the Walsh spaces of W64, W32 and W16, respectively.

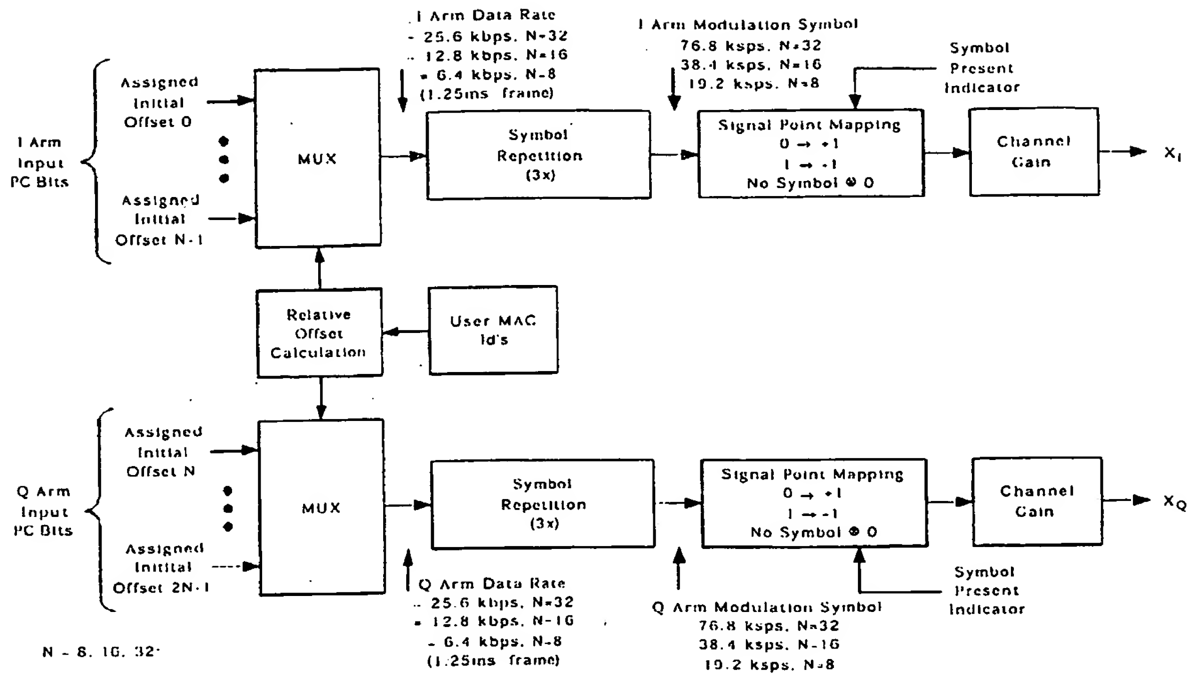


Figure 5.1. Forward Common Power Control Channel Structure

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